N70-42416

Tectonic Effects of Sea-floor Spreading on the Arabian Shield

Sea-floor Spreading in the Gulf of Aden and the Red Sea

The separation of the Arabian Shield from the African continent is our most recent example of continental drift and thus very suitable for a study of the tectonic effects of ocean floor-spreading.

The Carlsberg Ridge in the Indian Ocean,[1] can be connected with the ridge in the Gulf of Aden.[2] Although the southern Red Sea and Afar Depression are regions of great structural complexity,[3] it is inferred that in this area the Aden extension of the Indian mid-oceanic ridge splits into two branches: the NNW-Red Sea branch,[4] and the SSW-East African Rift System.[5]

Linear magnetic anomalies over the Gulf of Aden and Red Sea rift troughs are consistent with the hypothesis of sea-floor spreading.[6] The emplacement of a quasi-oceanic crust in the Gulf of Aden and Red Sea rift areas resulted in the separation of the former Arabian-Nubian Shield into two continental blocks.

Reviewing recent oceanographic data we find that the Gulf of Aden and Red Sea should no longer be considered as simple graben structures. A more probable thesis is that they represent rift troughs in an early stage of development.

Comparison between the Gulf of Aden and Red Sea troughs show that the Aden rift trough is wider and therefore in a more mature or advanced stage of development.

Structural Implications

Volcanism, epirogeny and orogeny are closely associated with the tectonic development of the rift troughs.[7] The age and trend of four major regional features are considered as directly related to the tectonic history of the Gulf of Aden and Red Sea:

1) The volcanic history of the area can be divided into two clearly distinguishable volcanic cycles which differ in age and geographic occurrence. The earlier of these is the 'Trap Series' which is found only in the Gulf of Aden area (Fig. 1) and ranges in age from Late Cretaceous into the early Miocene; its most active phase of volcanism was during Eocene to Oligocene time. The later cycle is represented by the 'Aden Volcanics' belt, which extends from the Afar Depression (East African Rift System) over the West Arabian Shield to southeastern Turkey (Fig. 2). These volcanics encompass Miocene to Recent time with maximum eruptions during the Plio-Pleistocene.

2) Two different sets of epirogenic warps can be recognized which are essentially parallel and adjacent to the rift troughs. a) During the Early Cretaceous structures

related to the Gulf of Aden (Fig. 1) first appeared. By the Late Eocene and Oligocene times the Hadramawt geanticlinorium,[8] the Rub Al Khali Syncline, the Arabian Interior Homocline[9] and the Nafud Basin had reached their present configuration.

b) In late Cretaceous time we find the first indications of younger epirogenic structures which parallel the Red Sea (Fig. 2). They occur only on the North Arabian Shield where the structures associated with the Gulf of Aden die out. During the Plio-Pleistocene, the outline of the present morphology of the Ras en Naqb Escarpment, Jafr Depression, Bayir Uplift, Wadi Sirhan Basin,[10] Rutba Arch and the Mesopotanian Syncline was developed.

3) Orogenic phases of the neighboring mountain belts are generally correlative with epirogenic movements observed on the shield. The Toros-Zagros mountains which surround the northern and northeastern edge of the consolidated Arabian Shield developed from the tectonic deformation of the unstable Thetys geosyncline. Like most of the Gulf of Aden related structures, the Toros chains and their S-shaped foreland belt (the Sinai-Lebanon-Palmyra Arch), which are located on the northern side of the Arabian Shield opposite to the Gulf of Aden, are primarily of Late Eocene-Oligocene age.[11] The Zagros mountains, which parallel the Red Sea are younger; having been folded since the Miocene.

4) The different movements of the Arabian Shield along pronounced fault systems, such as the initial Red Sea fault system and the Levant fault zone, are characterized by lateral displacements.[12]

The chronology of the structural evolution of Arabia can be separated into two general phases:

Phase I - The Gulf of Aden extension of the Carlsberg ridge which first became active in Early Cretaceous time and continued to develop in several phases which culminated during Late Eocene time. Spreading in the Gulf of Aden resulted in the NNW-movement of the Arabian Shield (Fig. 2). Left-lateral movement along the initial Red Sea-Suez fault system allowed for the separation of Arabia from the Nubian Shield. The shield area itself underwent repeated compressional stresses which were manifested as epirogenic warping (Fig. 1). Several phases of orogenic folding and thrusting in the more unstable margins of the Arabian Shield are the effects of the northward drift of Arabia. Volcanism peripheral to the Western Aden trough was confined in large part to the marginal fault systems.

Phase II - The evolution of the Red Sea Trough post-dates (Fig. 2) that of the Gulf of Aden. Paleogeographic reconstructions indicate that movements began in the Late Cretaceous. However, major tectonism occurred during Miocene and even in recent times. Associated volcanism, epirogeny and orogeny on and around the Arabian Shield is very similar to that which accompanied the spreading in the Gulf of Aden.

The estimated extension in the Suez Graben cannot account for the total amount of separation in the Red Sea. It is therefore suggested that the NE-movement of Arabia, associated with the spreading in the Red Sea occurred along the Levant (Aqaba-Orontes) fault zone.

Discussion

The structural evolution of the Arabian Shield implies that the tectonic forces that caused orogenic and epirogenic movements and volcanism originated within the rift roughs, and are related to sea-floor spreading.

It is of interest to note that even stable cratonic areas show a stress reaction in form of epirogenic warping. Since such broad deformations influence deposition and erosion, marine transgressions and regressions, they may control sedimentation conditions on the continents and adjacent shelf regions. This would allow us to reconsider and explain paleogeographic developments from a new aspect; for it suggests that unconformities and the concept of the stratigraphic sequence are related to sea-floor spreading in adjacent ocean basins.

Continuous seismic reflection profiles in the oceanic basins also show broad warps in addition to folding and fracturing of bottom sediments.[13,14] This indicates that older parts of oceanic crust react in a very similar way to what was described above for the continental crust of a cratonic area.

Acknowledgments

This study was supported by funds from Deutsche Forschungsgemeinschaft, Germany (Bu 183/1+2), National Science Foundation (GA-1601, GA 590) and NASA NGL-44-004-001 ~~(NSG 269-62)~~. I am greatly indebted to Dr. S. Alpan, M.T.A., Ankara, Dr. M. Barber, UNESCO, Amman, Dr. F. Bender, Geol. Bundesanstalt, Prof. Dr. R. Brinkmann, Ege Universitesi, Izmir, Dr. G. F. Brown, U.S.G.S., Drs. M. Halpern and C. E. Helsley, Southwest Center for Advanced Studies, His Excellency Dr. F. Kahbani, Jeddah, Dr. Ranoux, B.R.J.M. and numerous others not named here for their help.

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